

Photon-beam experiments and new light physics

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On behalf of all LOI authors

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- 1 Letter Of Interest
- 2 Photon-beam and new light physics searches
- 3 Compton vs. Primakoff kinematics
- 4 Tagged photon-beam fixed-target experiments
- 5 Expected sensitivities
- 6 Conclusions

Snowmass2021 - Letter of Interest

Photon-beam experiments and new light physics

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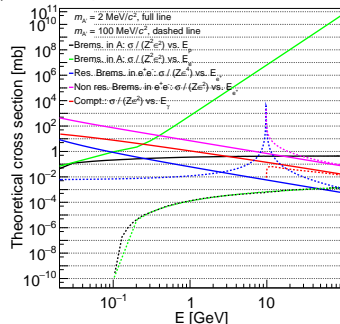
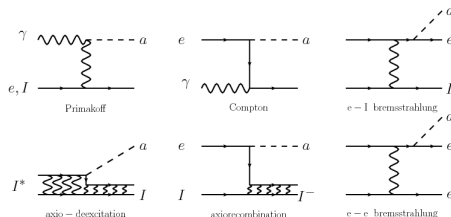
- LOI, The JLab Eta Factory (JEF) Experiment, Liping Gan et al.
- LOI, Searching for new light hidden particles with η and η' mesons, Sean Tulin et al.

Photon-beam and new light physics searches

Focus on new light physics produced off a nucleon, nucleus, or atomic electron

- $\gamma N \rightarrow X N$ (D. Aloni et al. PRL 123 (2019), arXiv:1811.03474 but for ALP case)
- $\gamma A \rightarrow X A$ (D. Aloni et al. PRL 123 (2019), arXiv:1811.03474 but for ALP case)
- $\gamma e^- \rightarrow X e^-$ S. S. Chakrabarty et al. arxiv:arXiv:1903.06225

Where: X = dark scalar, pseudo-scalar, vector, or pseudo-vector - N : nucleon - A : nucleus - e^- : electron
 X is either invisible or visible i.e. decays $X \rightarrow \gamma\gamma$ or $X \rightarrow l^+ l^-$ (l = lepton)



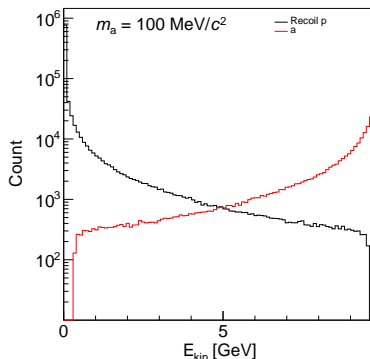
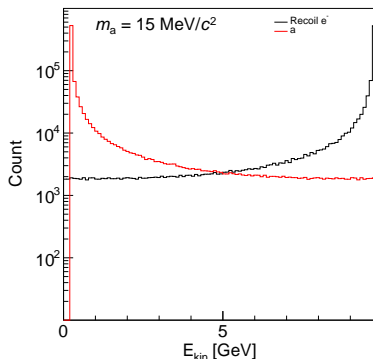
Typical invariant mass bump search or missing mass bump search but what if polarized photon-beam and/or nucleon or electron target are used? C.-Y. Chen and al in prep.

Add new observables to the search - single and double polarization observables

Compton vs. Primakoff kinematics

For $E_\gamma = 10$ GeV

- In Compton process most of the incident photon-energy is transferred to the recoil electron
- In Primakoff process most of the incident photon-energy is transferred to ALP
- Compton
- Primakoff



Compton kinematics facilitate an invisible search, Primakoff off nucleus cross section $\propto Z^2$

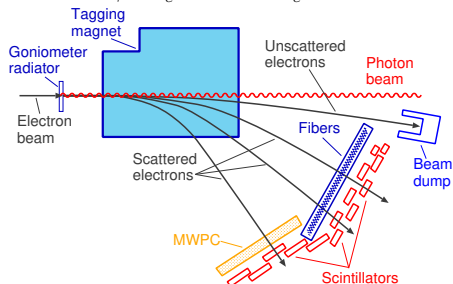
Photon-beam produced by bremsstrahlung

$$e_{\text{accelerator}}^- A \rightarrow e^- A \gamma$$

• A:

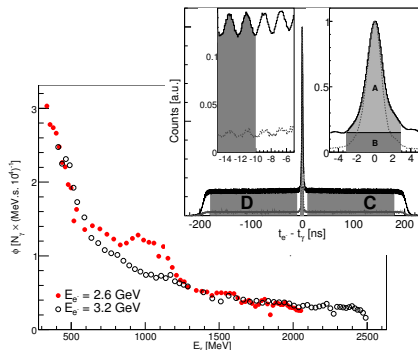
- $\sim 100 \mu\text{m}$ Cu for unpolarized photon beam
- $\sim 100 \mu\text{m}$ C (diamond) for linearly polarized photon beam
- Emitted (unpolarized) photon energy spectrum: $\Phi \sim \frac{1}{E_\gamma}$
- Emitted photon half-angle: $\langle \theta^2 \rangle^{\frac{1}{2}} = \frac{1}{e^-} = \frac{m_e c^2}{E_{\text{accelerator}}}$
- Electrons emitting bremsstrahlung deflected downwards by dipole magnetic field onto focal plane of tagging system

- Energy and timing extracted
- $E_\gamma = E_{\text{accelerator}} - E_{e^-}$



Typical tagging spectrometer setup.

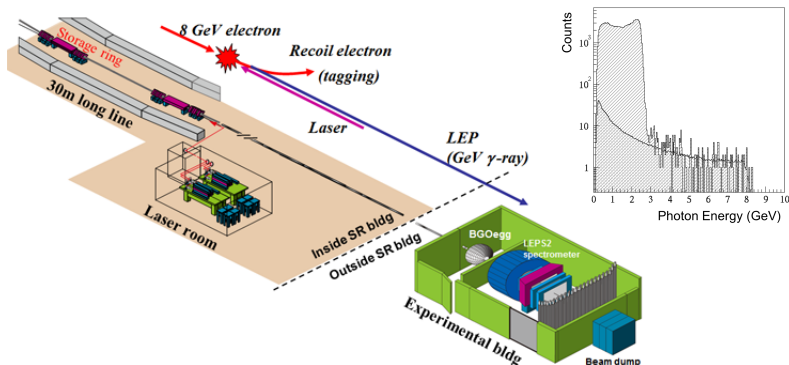
More details in I. Jaegle et al., EPJ A **47** (2011) 89



Photon-beam produced by Laser-backscattering

$e^-_{\text{accelerator}} \gamma_{\text{laser}} \rightarrow e^- \gamma$, inverse Compton process

- Tagged photons backscattered from 8 GeV electrons reach max. energies of 2.9 GeV
- Scattered electrons momentum analyzed by last bending magnet before straight section of beam line and then detected in tagging counter



Backscattering of laser light (eV) from high energy electrons (GeV).

More details in N. Muramatsu et al. NIM A737 (2014) 184-194

Photon-beam experiments

Experiments	Φ_γ [γ/sec]	E_γ range [GeV]	ΔE_γ [MeV]
GlueX	5×10^7	9 – 12	50
LEPS	5×10^6	1.4 – 2.4	12
LEPS2	5×10^6	1.4 – 2.4	12
FOREST	4.5×10^6	0.8 – 1.2	1
NPS/CPS	10^{12}	5 – 11.5	un-tagged
A2/MAMI	10^7	0.068 – 1.488	4
CB/ELSA	10^6	0.5 – 3.1	10
PRIMEX II	10^7	4.3 – 5.2	5

Table 1: Tagged photon-beam flux (Φ_γ), energy range, and detector resolution (ΔE_γ) for GlueX, LEPS, LEPS2, FOREST, A2/MAMI, CB/ELSA, and NPS/CPS. We also add the information of PRIMEX II, a past photon-beam experiment, for comparison.

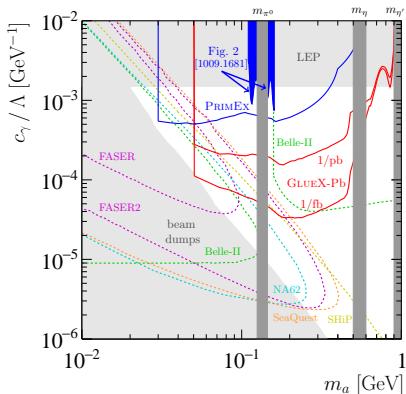
- Small experiments - “family size” - compared to Belle (II) or LHC
- But huge data sets collected since the last 20 years

Under exploited data sets

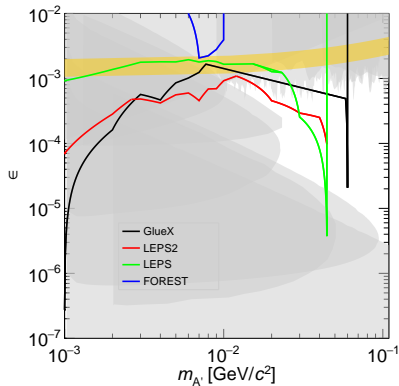
Expected sensitivities

For unpolarized photon-beam and targets

- Primakoff (D. Aloni et al.), nucleon and nucleus target



- Compton (S. S. Chakrabarty et al.), electron target, projected sensitivities on dark photon kinetic mixing for 1 month beam-time at FOREST (blue), LEPS2 (red), LEPS (green), and GlueX (black)



What are we gaining if new detectors are added - veto and/or vertex detector?

Conclusions

Photon-beam experiments can search for new light physics

- Study if adding new observables improves these searches - timescale Spring 2021
- Study if adding new detectors improves these searches - timescale Spring 2021
- Extract combined sensitivities - timescale Spring 2021

An ideal outcome would be that photon-beam experiments/theorists combined their work force when possible

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